FRontiers in dust minerAloGical coMposition and its Effects upoN climaTe (FRAGMENT)

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A. Panta	TUDA
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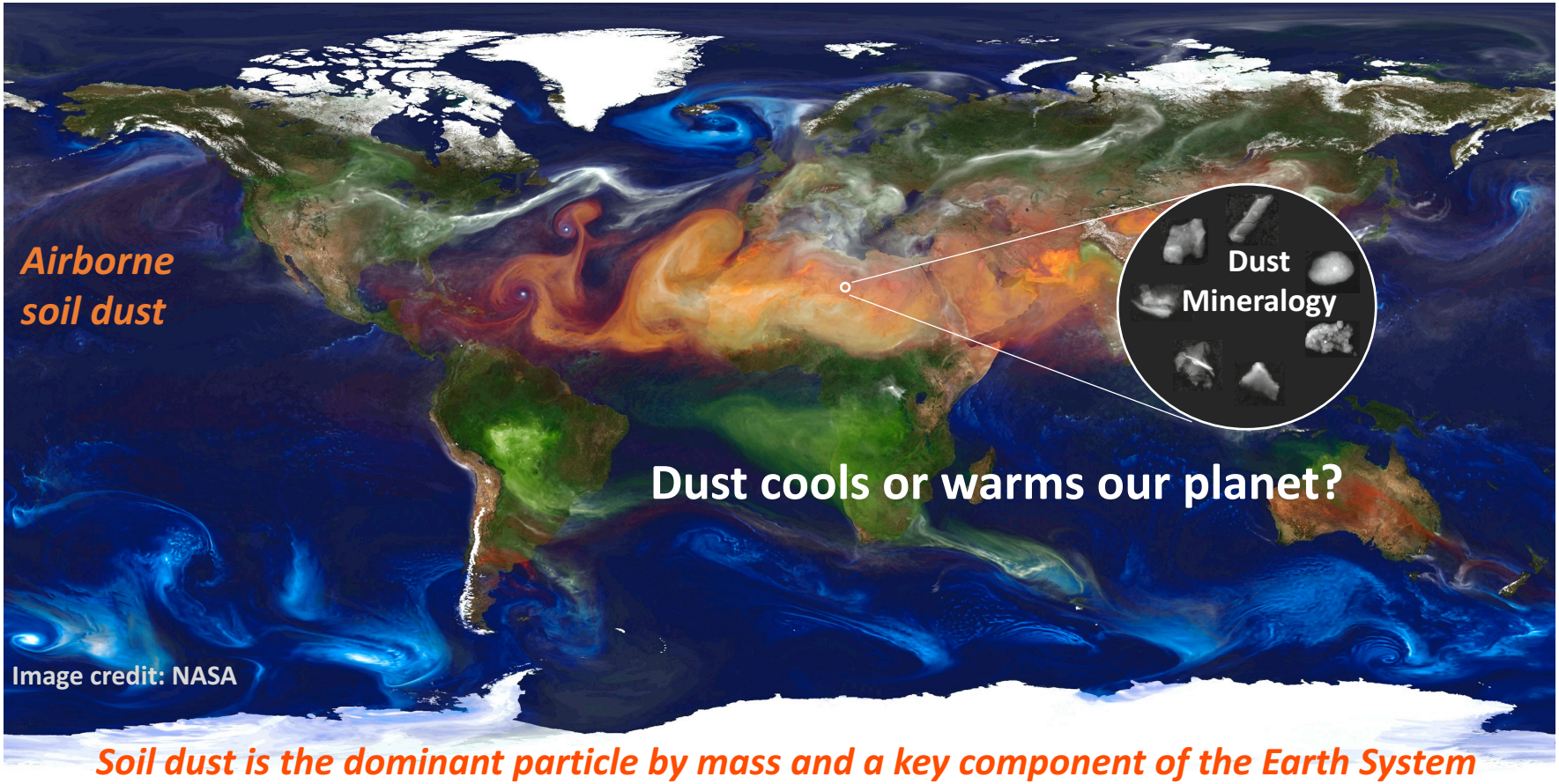
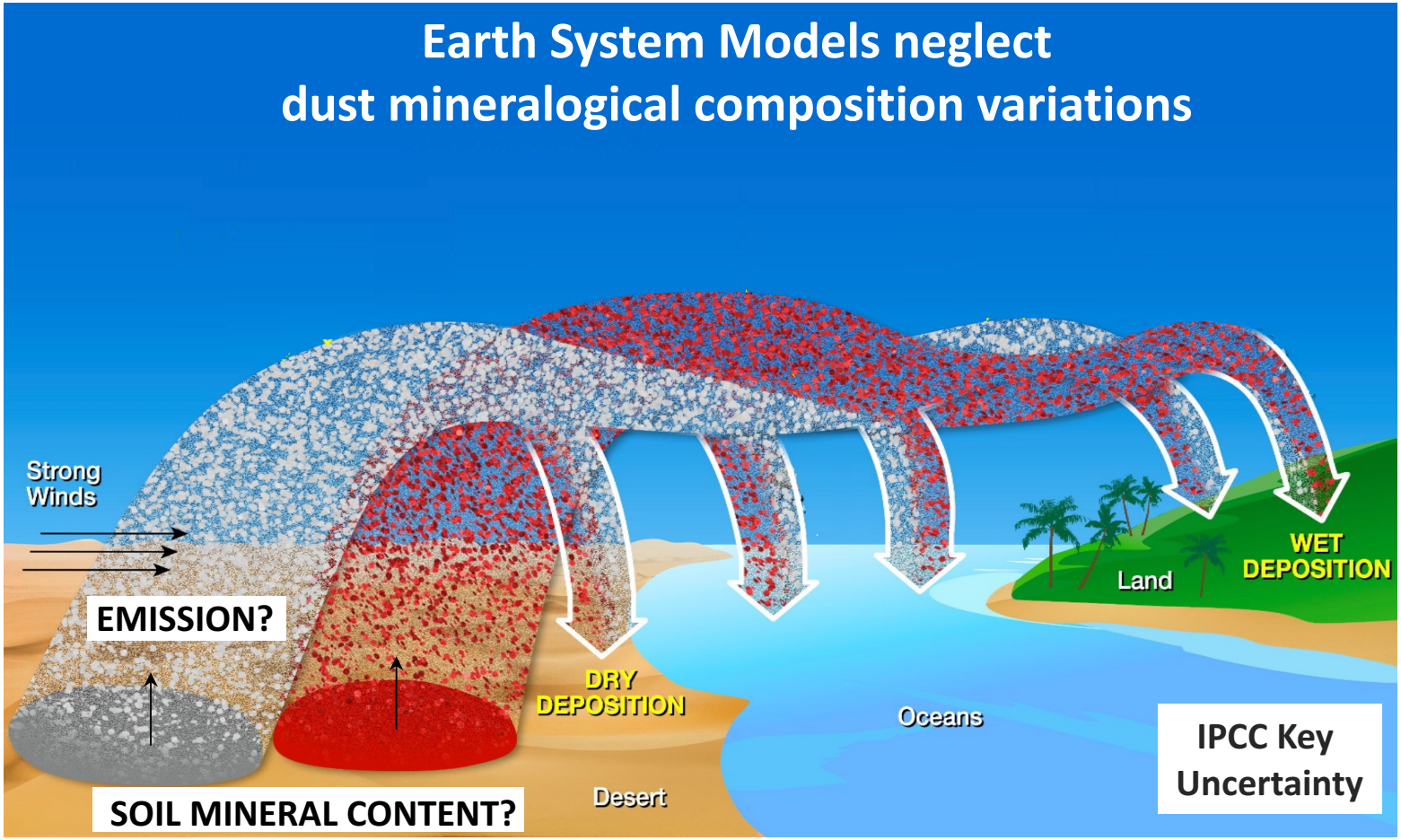
EGU General Assembly 2019, Vienna

FRAGMENT

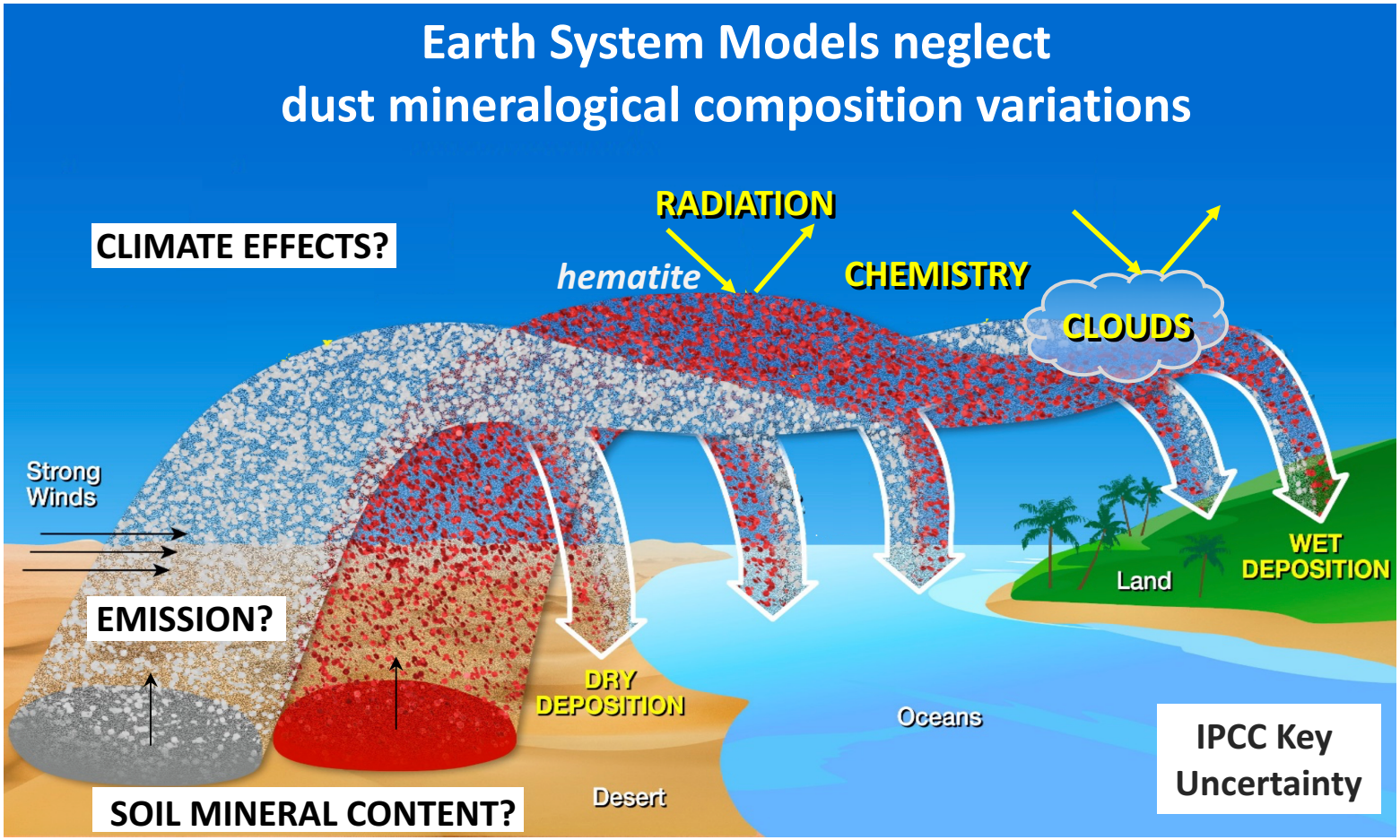


Soil dust is the dominant particle by mass and a key component of the Earth System

CONCEPT


Earth System Models neglect
dust mineralogical composition variations
Strong
Winds
EMISSION?
SOIL MINERAL CONTENT?
DRY
DEPOSITION
Desert
Oceans
Land
WET
DEPOSITION
IPCC Key
Uncertainty

CONCEPT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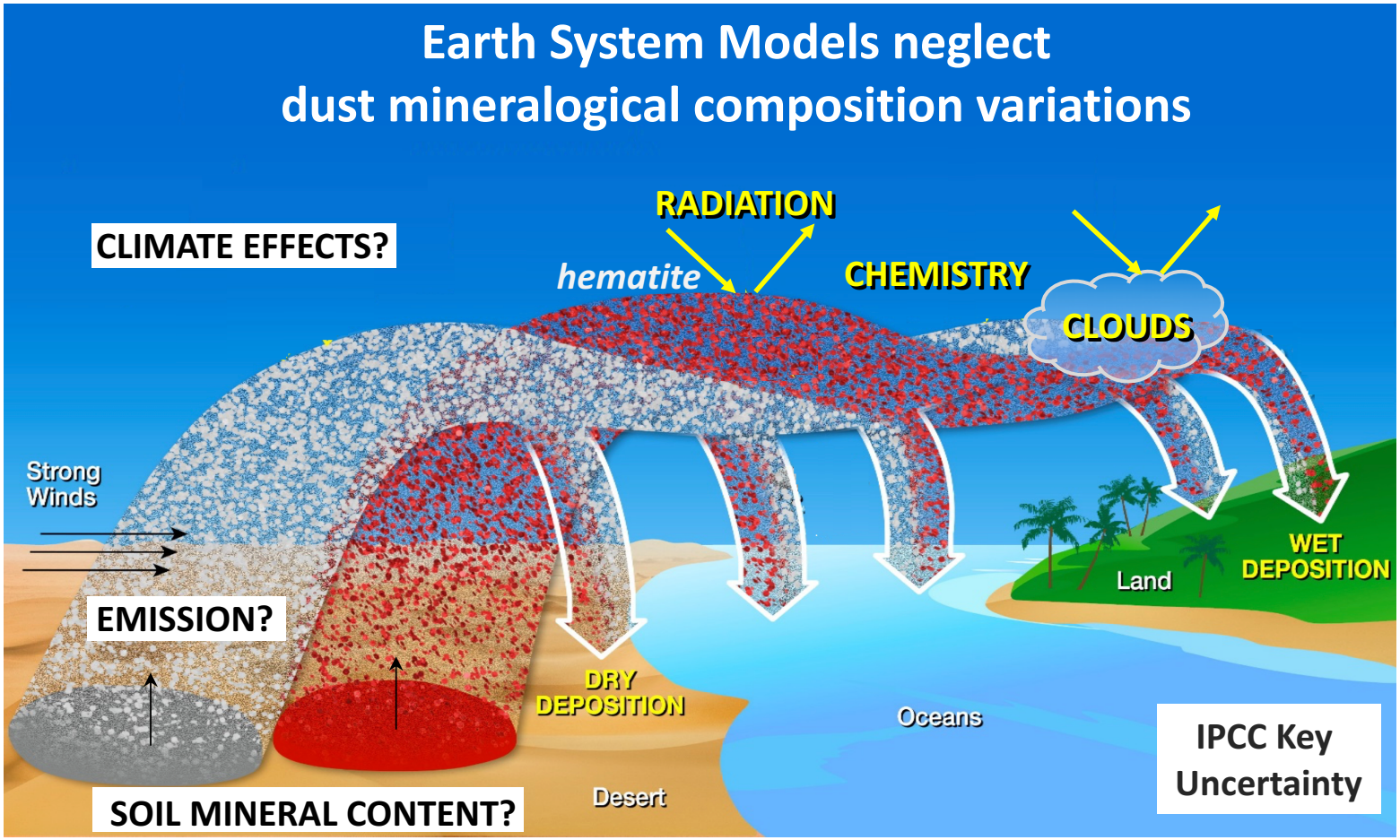
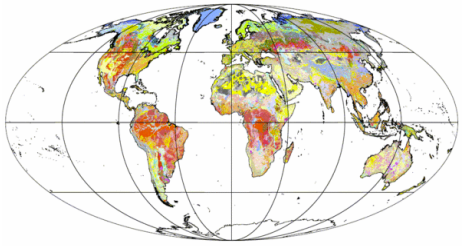


Constrain the global dust mineralogical composition
Understand and calculate its effects upon climate

Challenges addressed

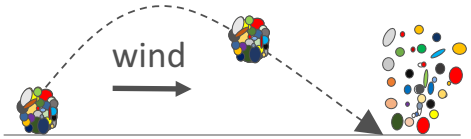
1

Global soil mineral content



2

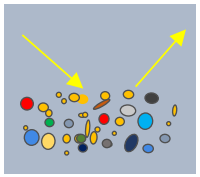
Emission of minerals

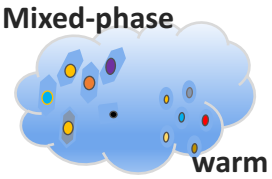


FRAGMENTation of aggregates

3

Role of mineralogy





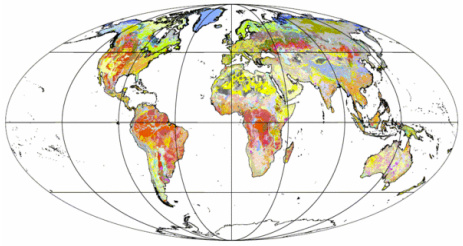
Radiation, Chemistry and Clouds

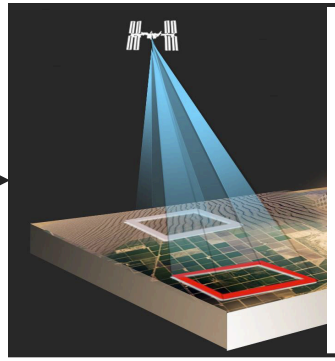
Challenges addressed

Methods

1

Global soil mineral content

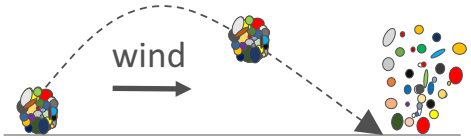




Space-borne spectroscopy
+
Airborne spectroscopy
+
Field campaigns

2

Emission of minerals



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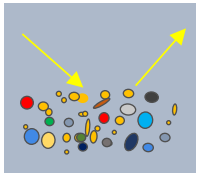

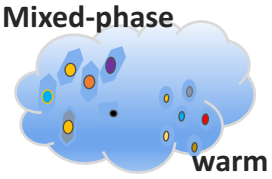

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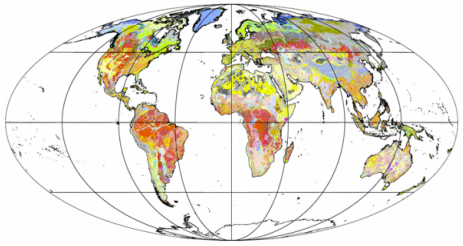

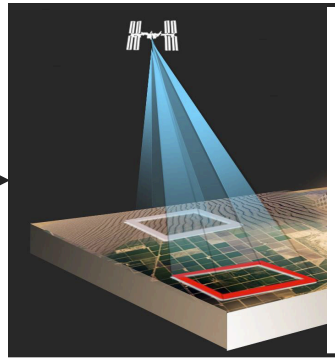

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+
Airborne spectroscopy
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Field campaigns

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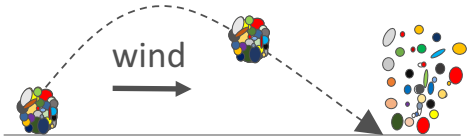
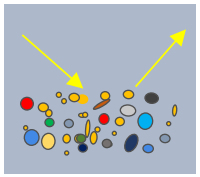


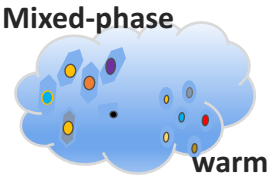
FRAGMENTation of aggregates

Proposed theory
+
Field campaigns
+
Laboratory analyses

3

Role of mineralogy





Radiation, Chemistry and Clouds

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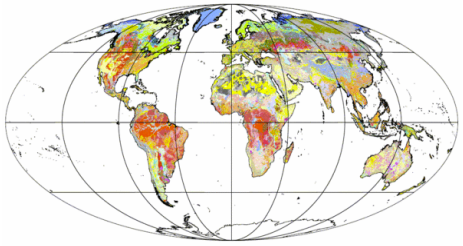

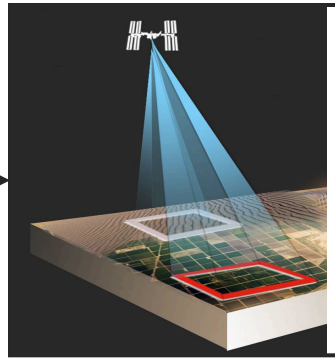

Space-borne spectroscopy
+
Airborne spectroscopy
+
Field campaign

2

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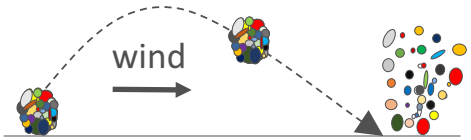

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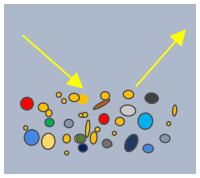

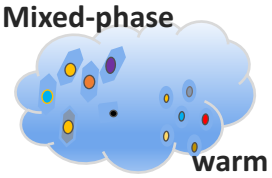

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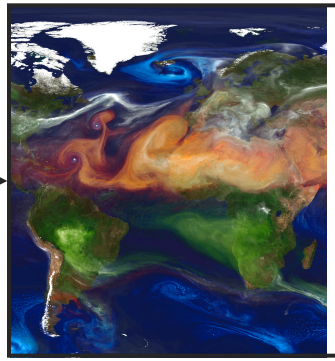
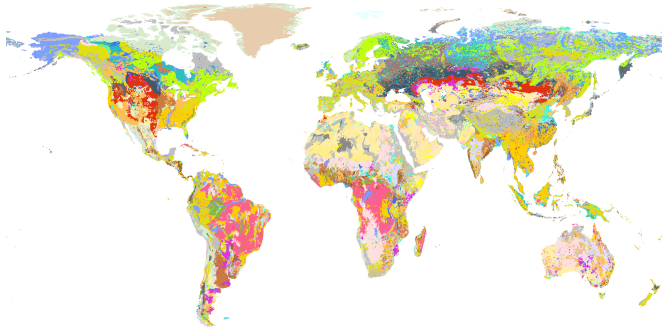


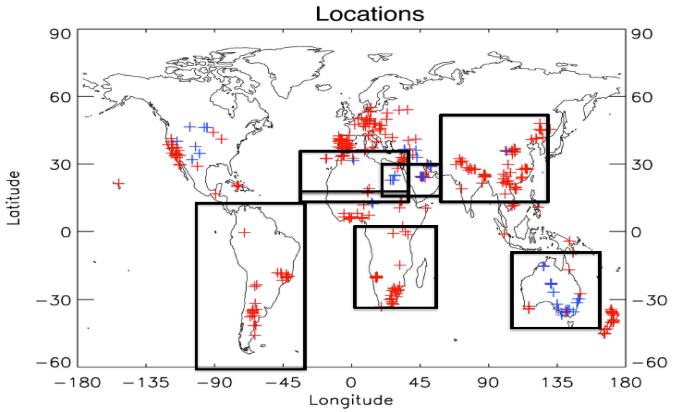
Modelling
+
State-of-the-art
+
New methodologies

Mapping of soil-surface mineralogy

- Claquin et al., 1999; Journet et al., 2014
- Currently 12 key minerals estimated
- 700 soil descriptions sampling 55 % of FAO soil units
- Many regions including prolific sources not sampled
- Massive extrapolation based on soil unit/type
- A number of assumptions to overcome the lack of data: for example on hematite and goethite size
- Soil analysis based on *wet sedimentation* (“*wet sieving*”), which breaks the aggregates found in undispersed soils subject to wind erosion.

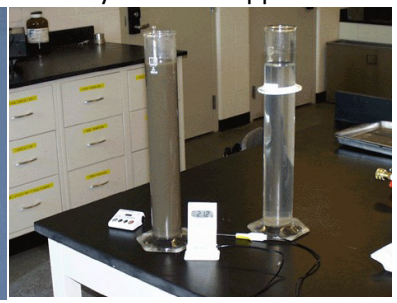


FAO soil types or units



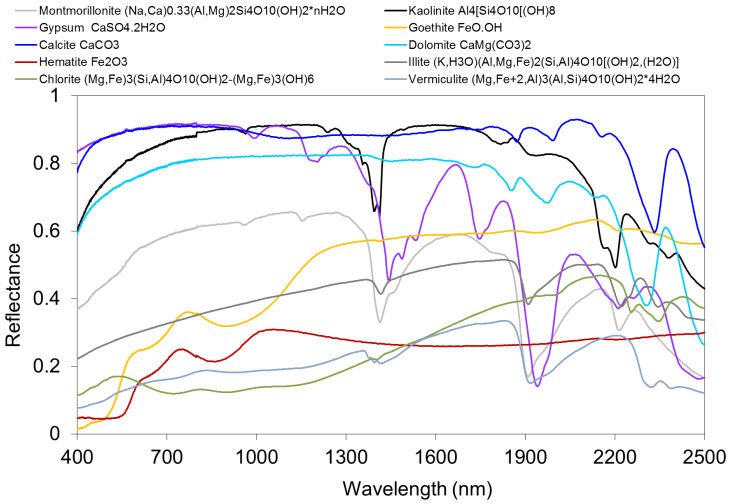
Sieves for mechanical analysis

Soil Hydrometer apparatus



Space borne hyperspectral imaging spectroscopy

VSWIR Spectra of Dust Source Minerals



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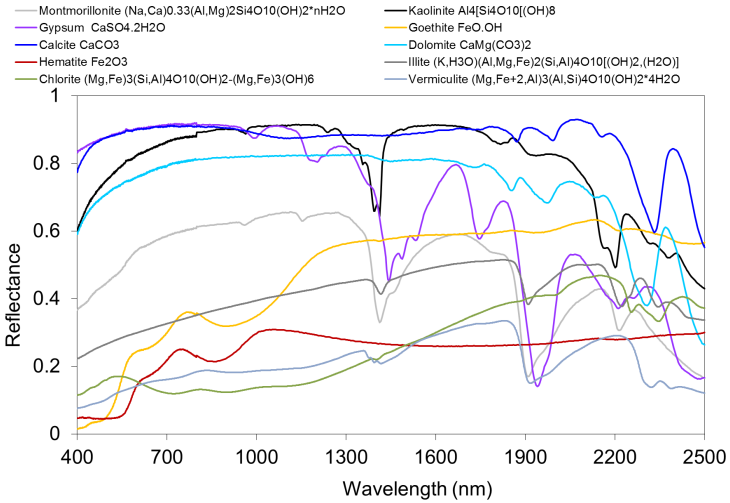
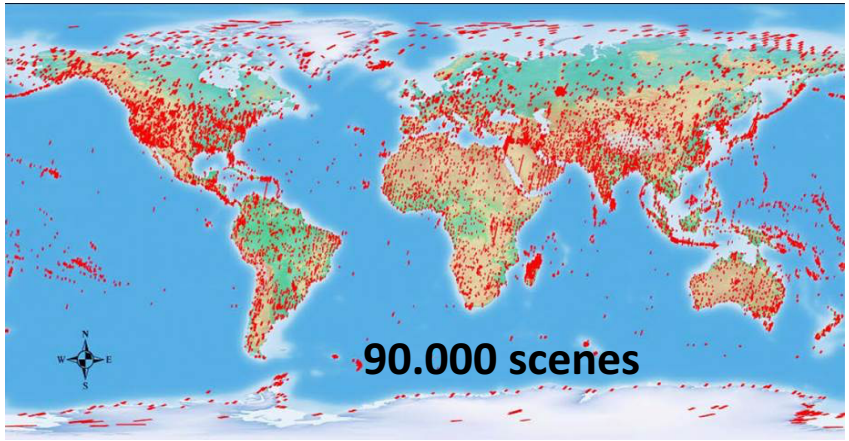


Hyperion: satellite hyperspectral sensor 0.4 to 2.5 µm, 242 spectral bands, 10nm spectral resolution, 30 m spatial with a SNR of ~50:1



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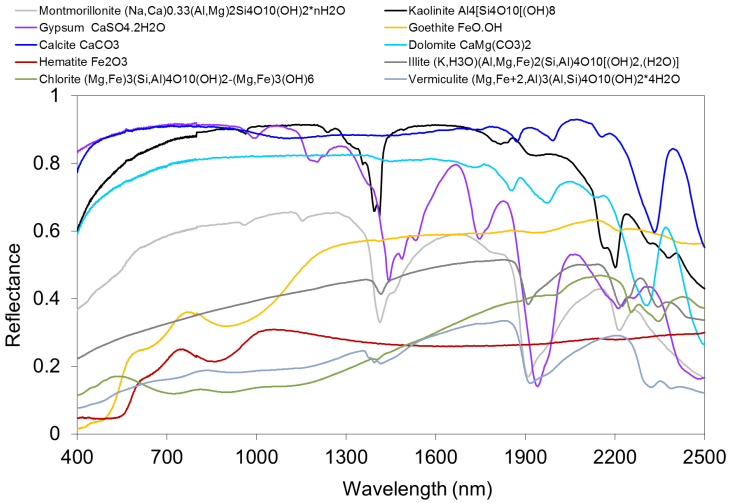

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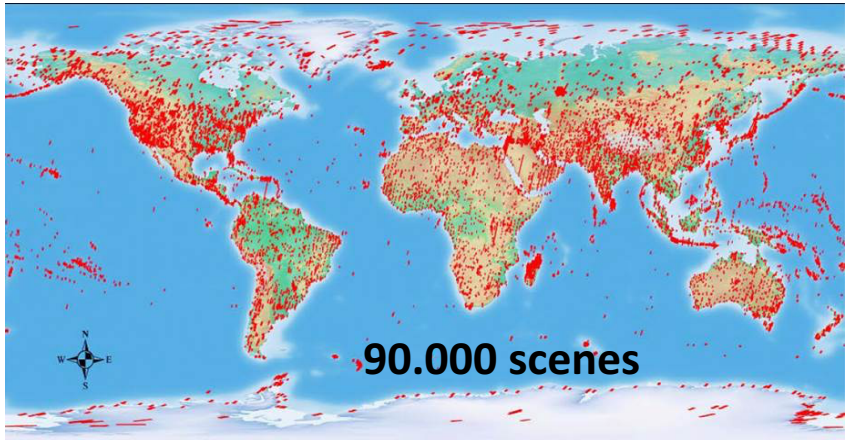
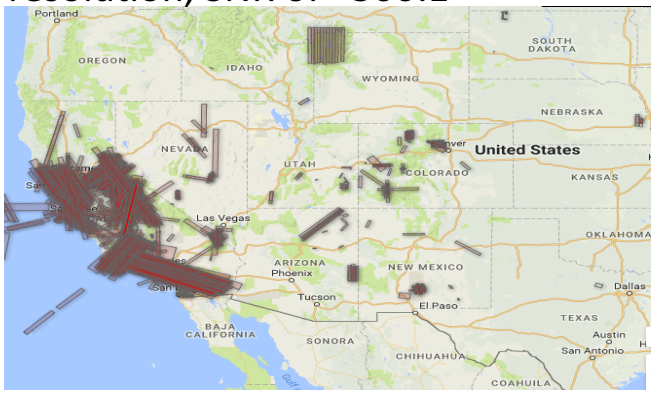


AVIRIS airborne scenes

0.4–2.5 µm, 224 bands, 10 nm spectral resolution, SNR of ~500:1



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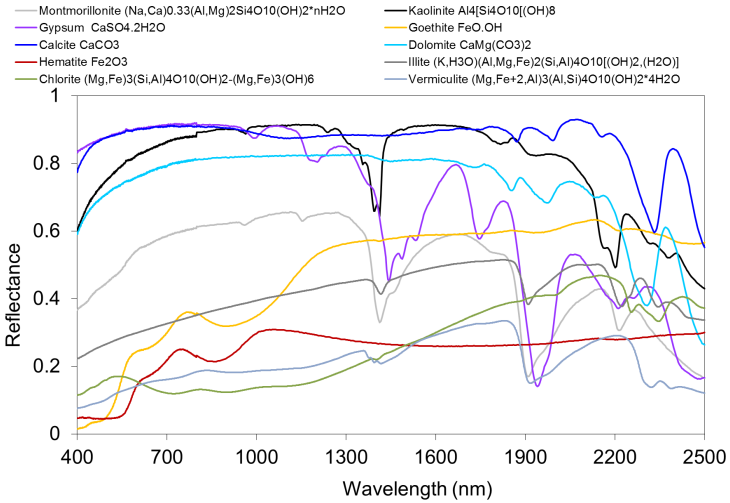

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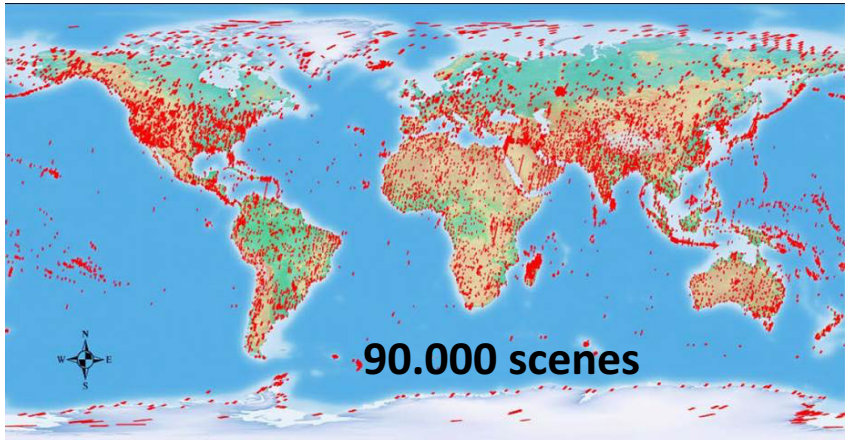

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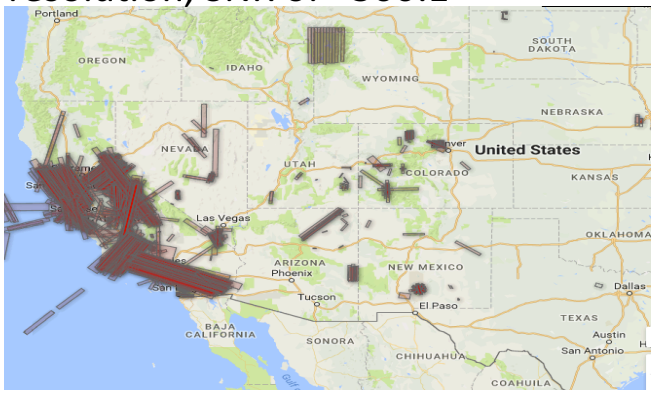
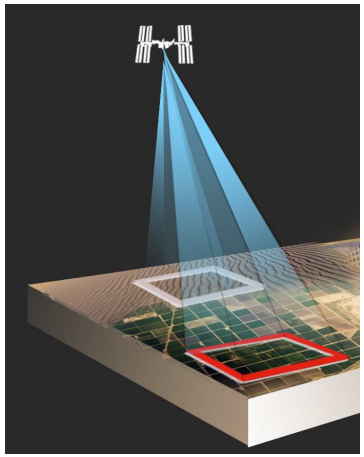


Coming soon (2021)!!!
NASA FUNDED
EMIT
Earth Surface Mineral Dust Source Investigation

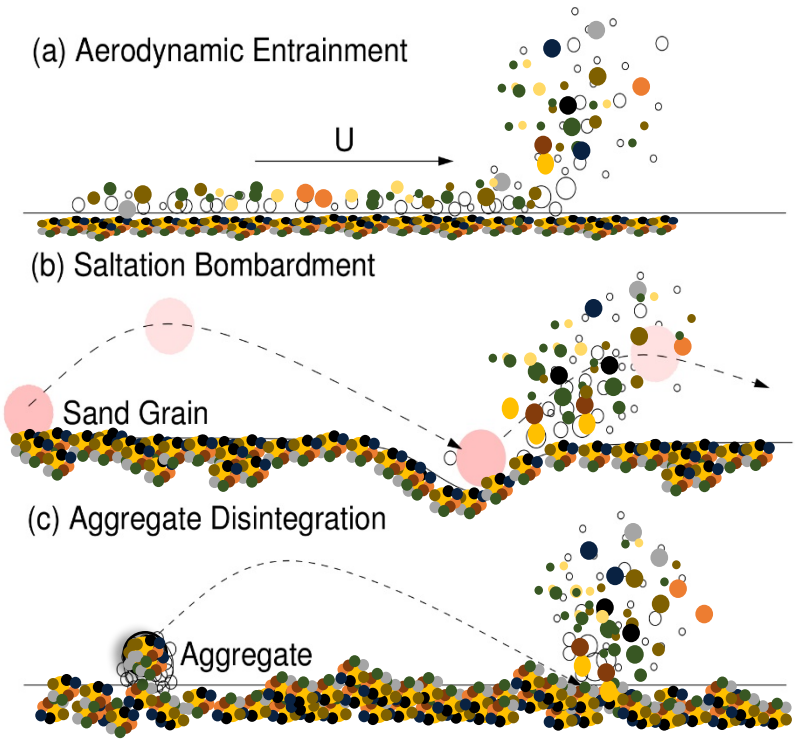


See Green et al. in this same EGU session

Emission of dust minerals

Emitted PSD of dust minerals is key to quantifying their climate effect

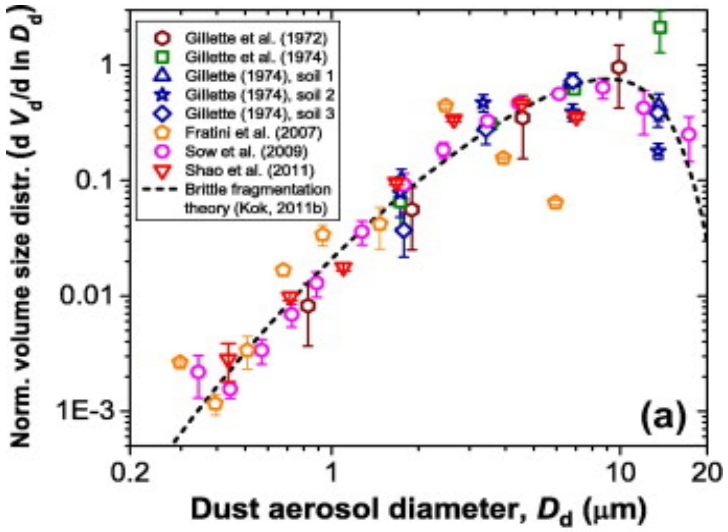
- Incomplete understanding of the physics
- Paucity and incompleteness of measurements
- Lack of (realiable) input data at global scale (e.g. soil PSDs)
- Lack of experimental studies tackling the relationship of the emitted PSD and soil-surface mineralogy
- Internal and external mixtures of different minerals important for climate impacts



Dust emission mechanisms (Shao et al. 2008)

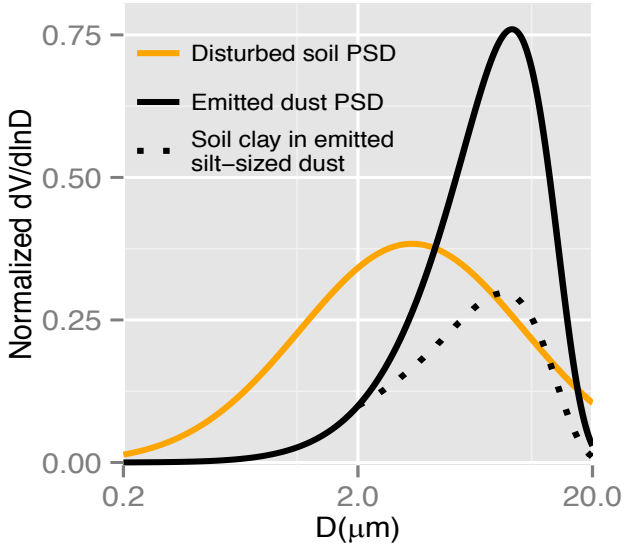
Emitted PSD and mineralogy in models

Brittle Fragmentation Theory auspicious for mineralogy as it is based on the soil dispersed PSD



Kok (2011)

$$\frac{dV}{d\ln D} = \frac{D}{C_V} u(D) \exp\left[-\left(\frac{D}{\lambda}\right)^3\right]$$



Scanza et al. (2015)
Perlwitz et al., 2015 (a,b)
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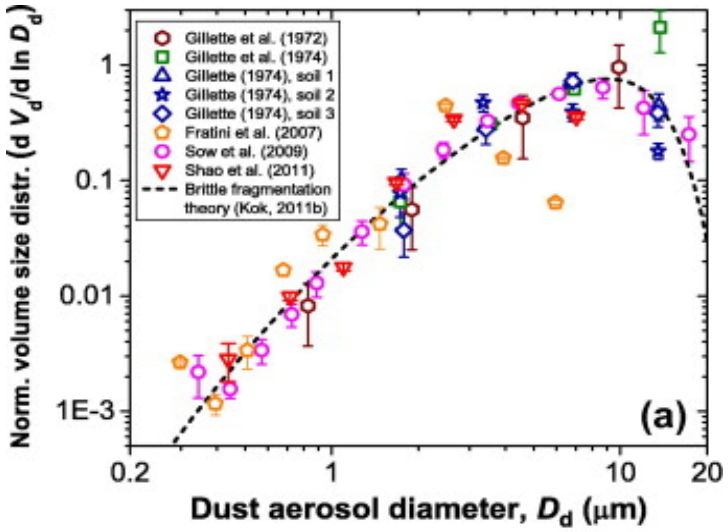

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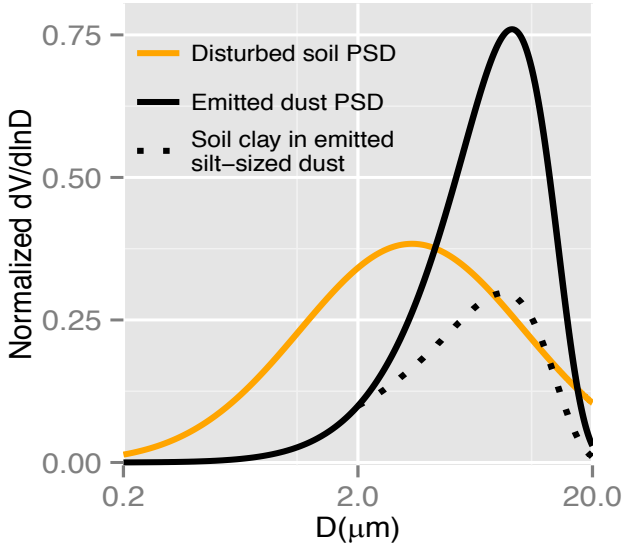

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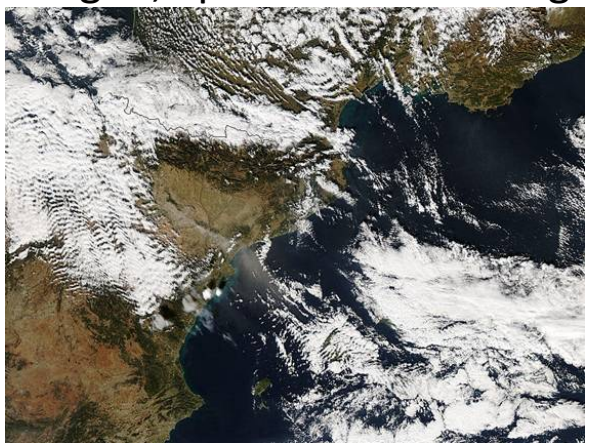
PRESS HERE for preliminary results and hypotheses (Pérez García-Pando et al., in prep)

Field Campaigns: Where, Why and When?

Aragón, Spain 2019 - testing



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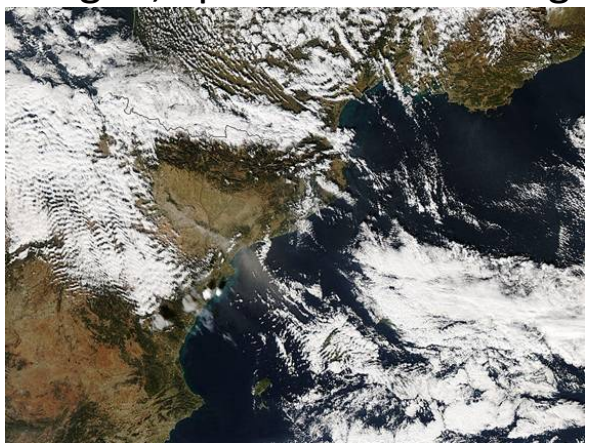

Morocco 2019 and 2021

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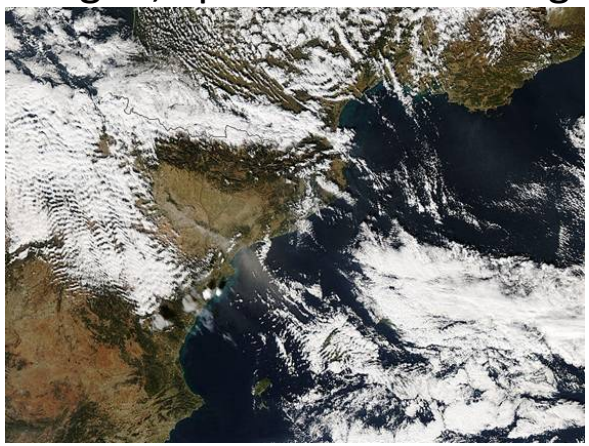

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Salton Sea and surroundings, US 2020

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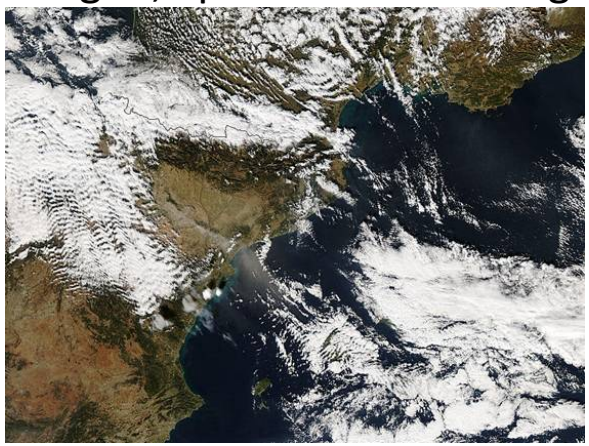

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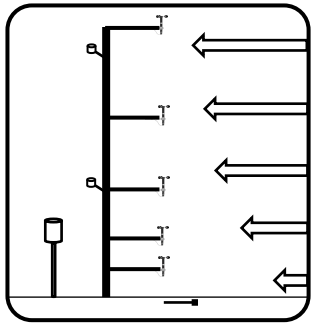
Salton Sea and surroundings, US 2020

Icelandic sources (HiLDA!) 2020

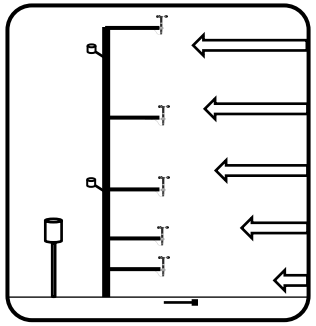
Field Campaigns: What?



Atmospheric forcing

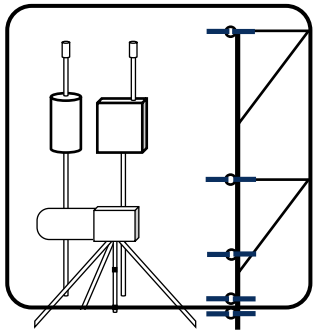
- 2D wind and temp profiles, 3D wind, turbulence, pressure
- Radiative fluxes
- Soil-surface humidity
- RH close to the ground
- Precipitation

Field Campaigns: What?



Atmospheric forcing

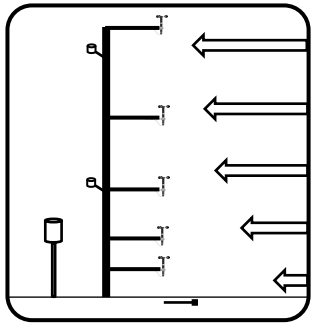
- 2D wind and temp profiles, 3D wind, turbulence, pressure
- Radiative fluxes
- Soil-surface humidity
- RH close to the ground
- Precipitation



Sand and Dust

- Time- and size-resolved vertical number and mass fluxes
- Size-segregated samples of suspended dust (compositional fluxes)
- Saltation flux (time/size resolved and bulk) – active and passive
- Absorption and scattering

Field Campaigns: What?



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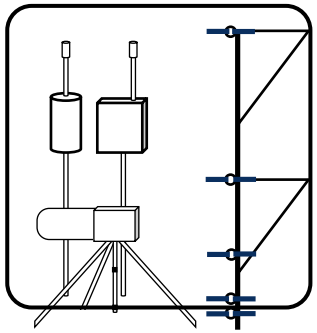

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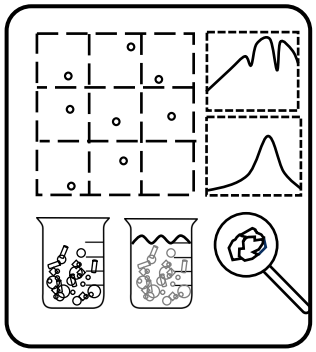
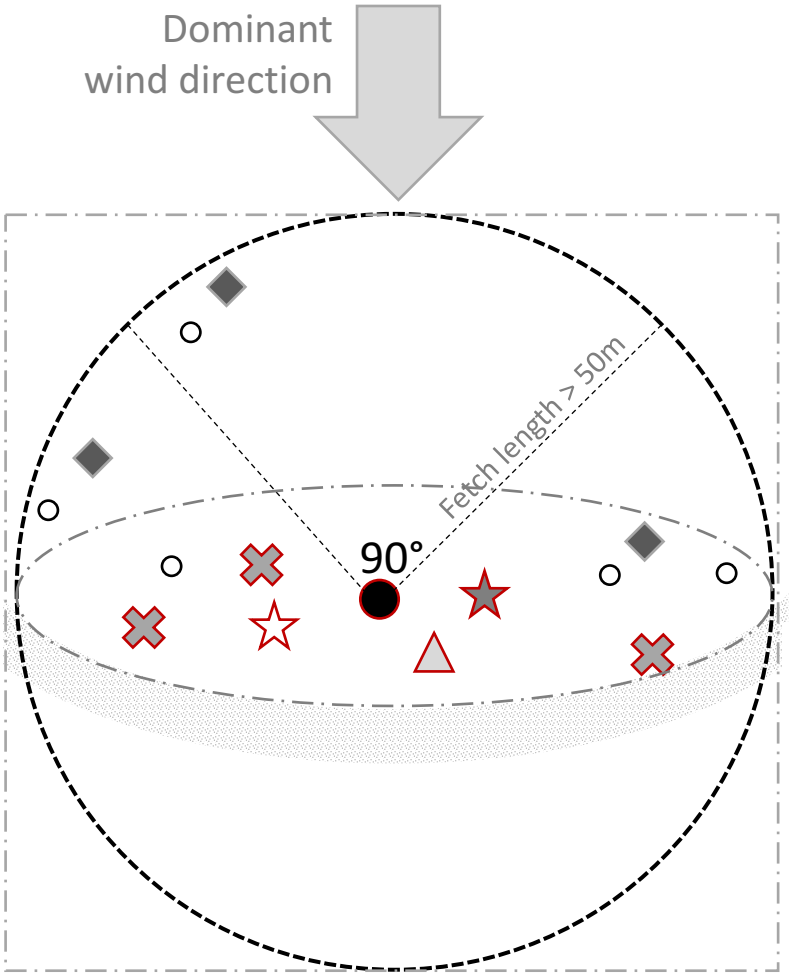


Soil sampling, surface spectroscopy and lab analyses

- Soil-surface sampling
- Surface composition (based on reflectance spectra + tetracorder)
- Dry soil aggregate stability, crust strength

- PSD in wet and dry dispersion of soil and saltation samples
- Size-resolved mineralogy, chemistry, morphology and mixing state of soil, saltation and dust samples (XRD, TEM, BSED,..)
- Composition of soil and aeolian samples and sub samples based on spectroscopy

Tentative schematic of the field setup



10m tower: 5 2D sonic anemometers, 4 temp sensors with aspirated shield, 1 RH/T sensor, P sensor, 2 3D sonic anemometers, Optical counter
2 Optical counters at 2 m and 4 m 2 Multistage Cascade impactors Polar nephelometer and aethalometer Common inlet
2 Optical counters at two heights
3 Saltation sensors, 2 or 3 heights each
5 MWAC masts (2m, 5 heights: 0.1, 0.2, 0.5, 1, 2m)
Radiometer and pluviometer
Soil-surface moisture sensors
Additional instrumentation

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

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European Research Council
Established by the European Commission

Thank you

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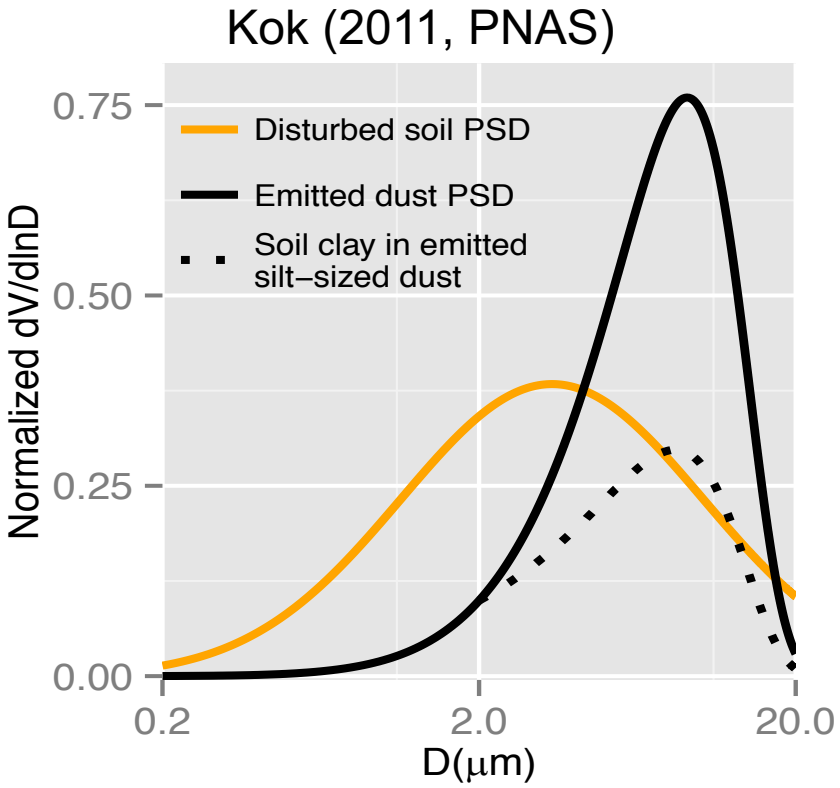
Brittle fragmentation theory



Measurements suggest emitted size distribution is approximately invariant < 15-20 μm

$$\frac{dV}{d\ln D} = \frac{D}{C_V} u(D) \exp\left[-\left(\frac{D}{\lambda}\right)^3\right]$$

The net effect of aggregation and fragmentation is to increase the silt-sized fraction at the expense of clay

Simulations

- Soil composition:

  Claquin et al. (1999)

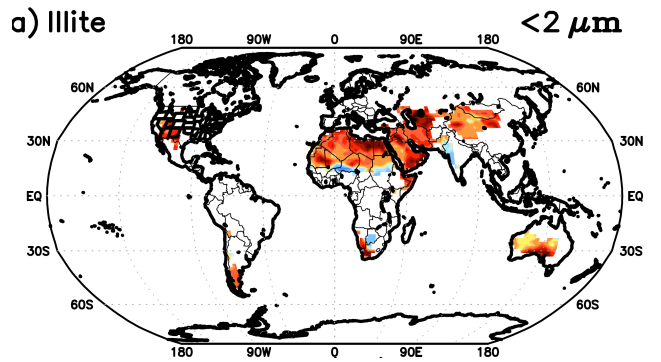
- NASA GISS/ModelE

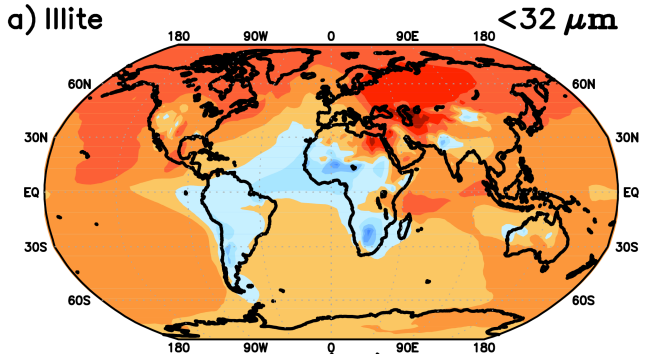
- 2 x 2.5 deg, 40 layers

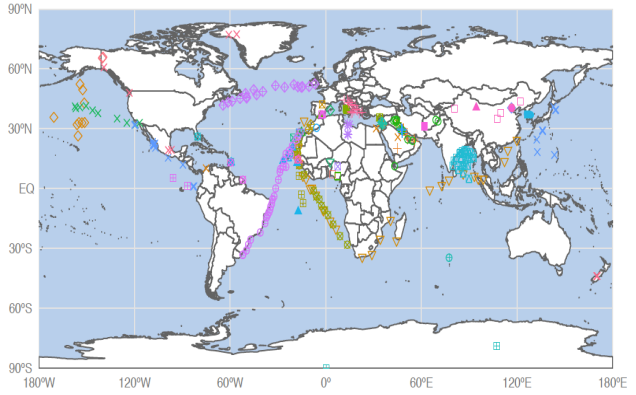
- 4 experiments

- Period 2002-2010, winds nudged to reanalysis

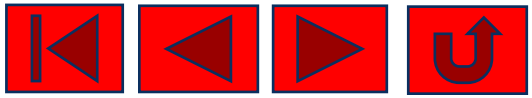
- Evaluation based on a new compilation of observations from 60 studies available in Perlwitz et al. (2015, ACP)





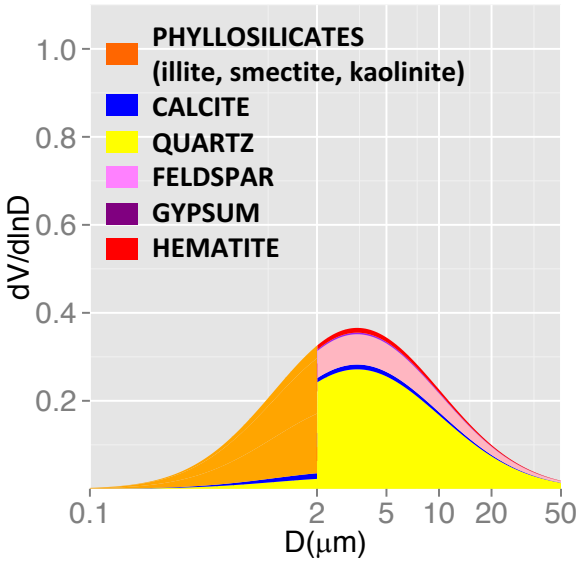


Experiments



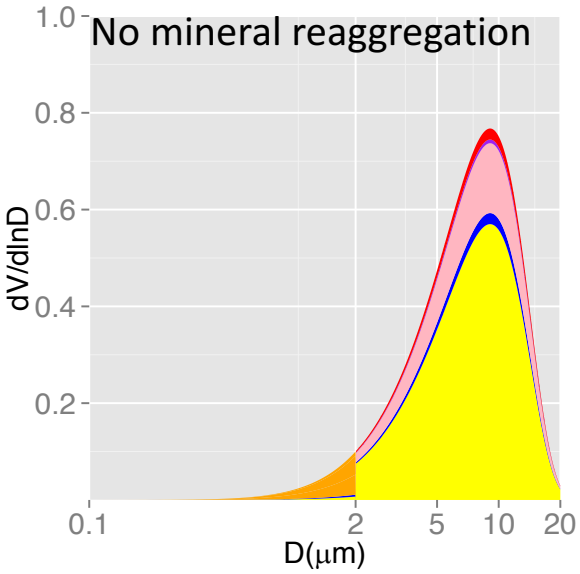
SMF

Emitted as wet sieved soil



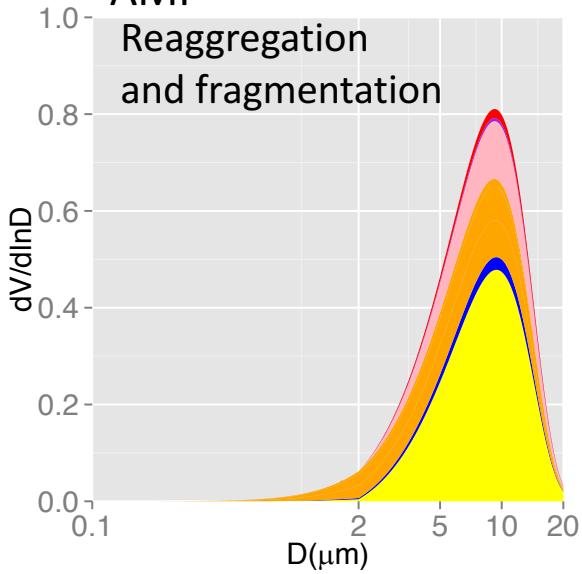
Realistic dust size distribution

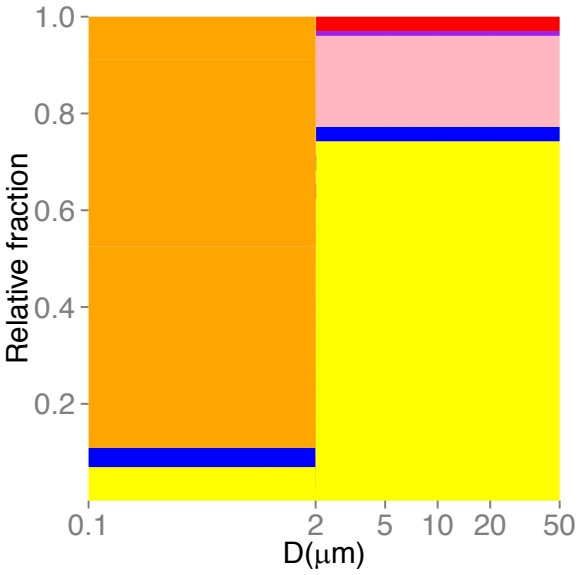
No mineral reaggregation

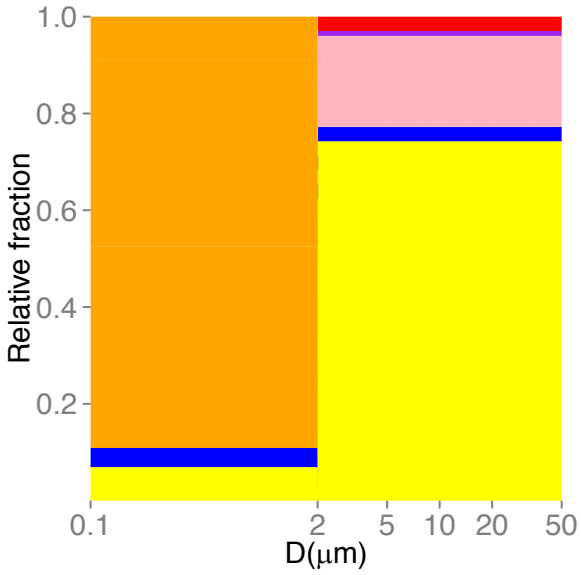


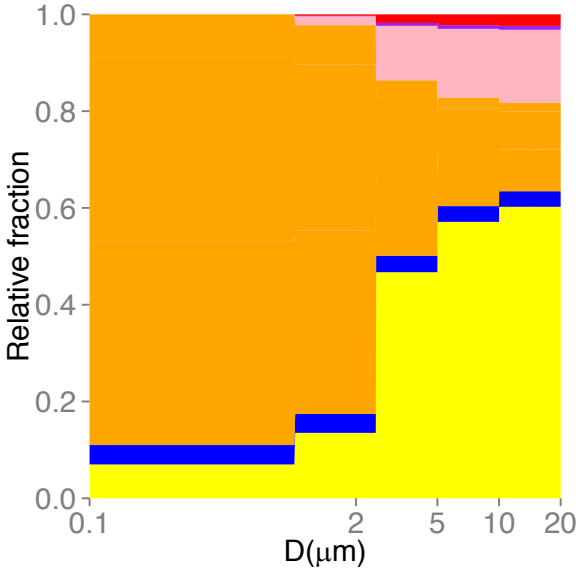
AMF

Reaggregation
and fragmentation









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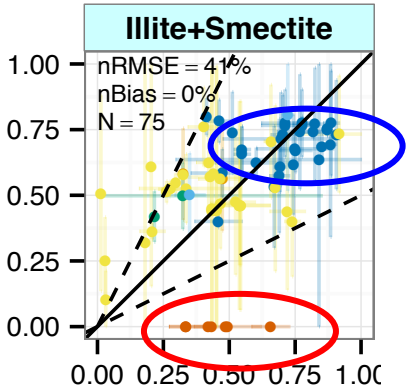
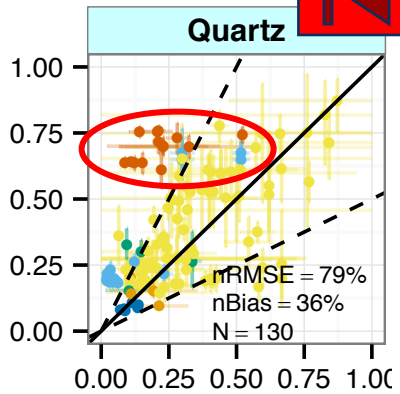
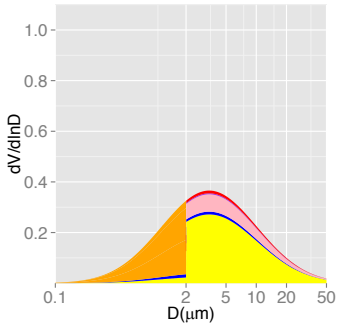
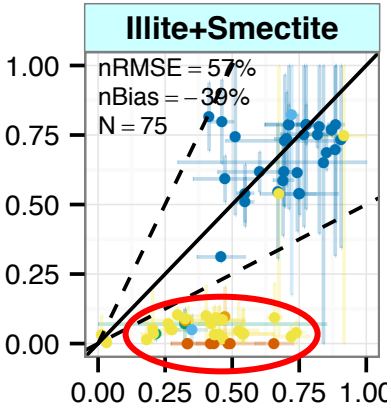
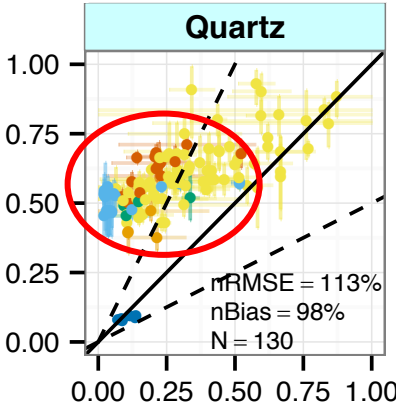
Soil reaggregation and fragmentation

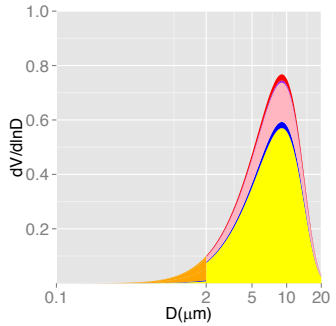


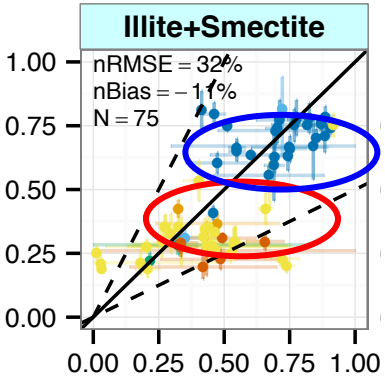


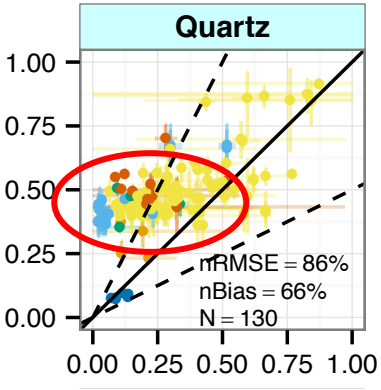


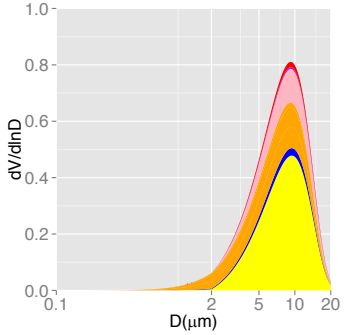












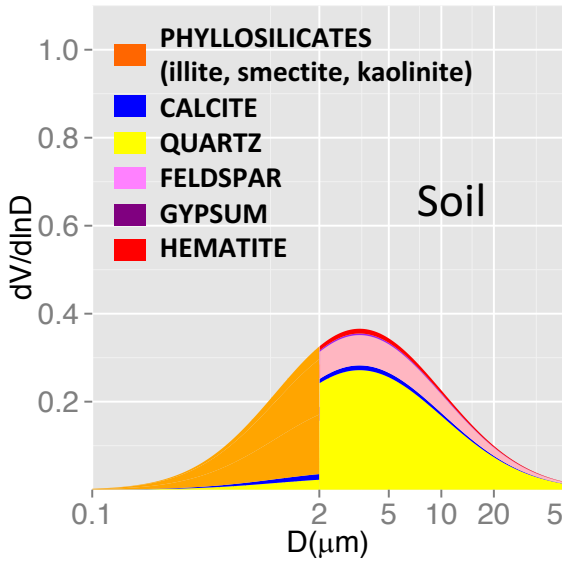
Size Group

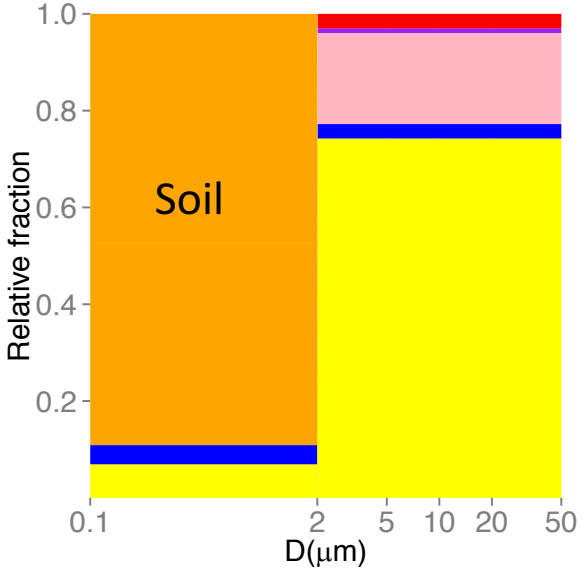
Observations

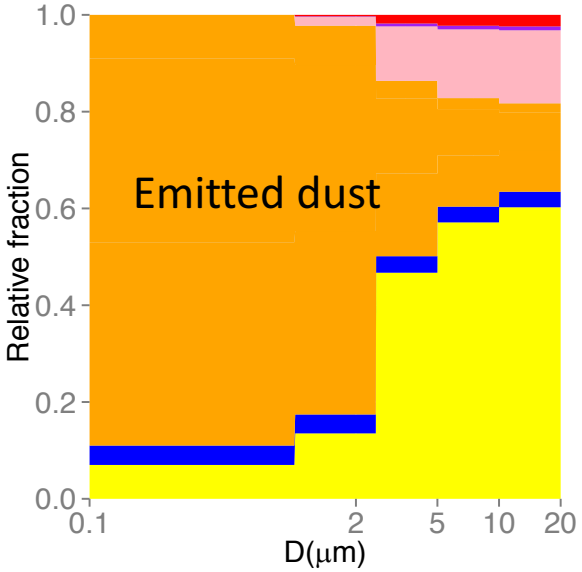
Bulk | < 5 μm | < 10 μm | < 20 μm | < 2 μm | > 2 μm

Fitting Soil Mineral Size Distributions

Reaggregation and fragmentation







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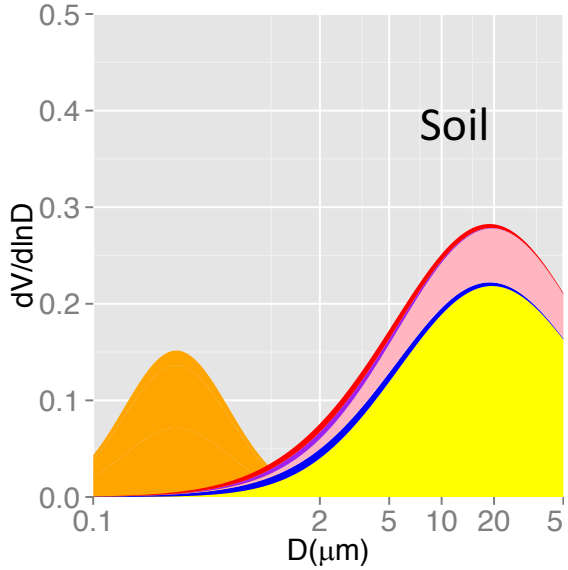

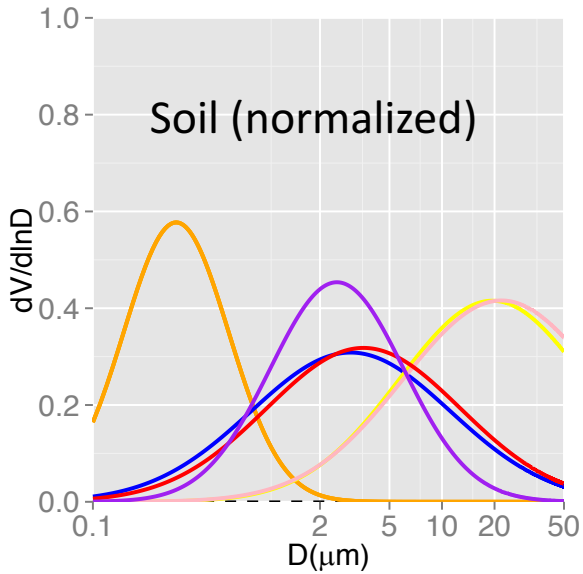

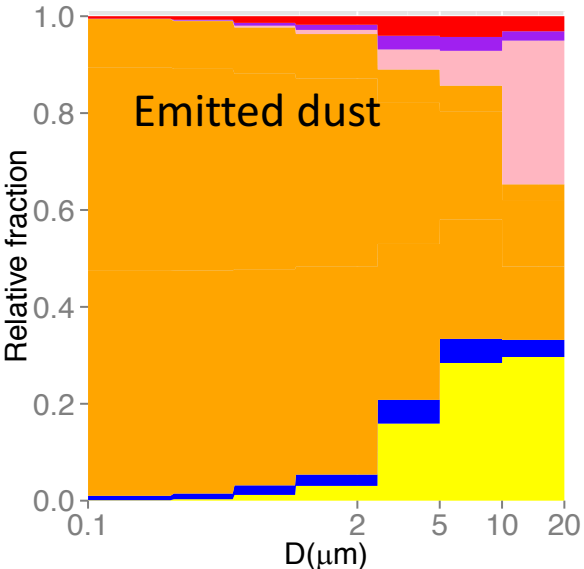

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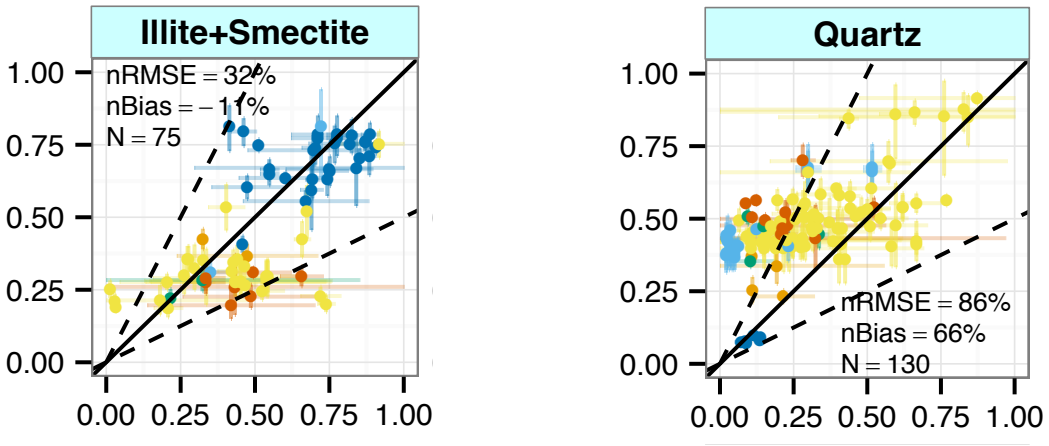

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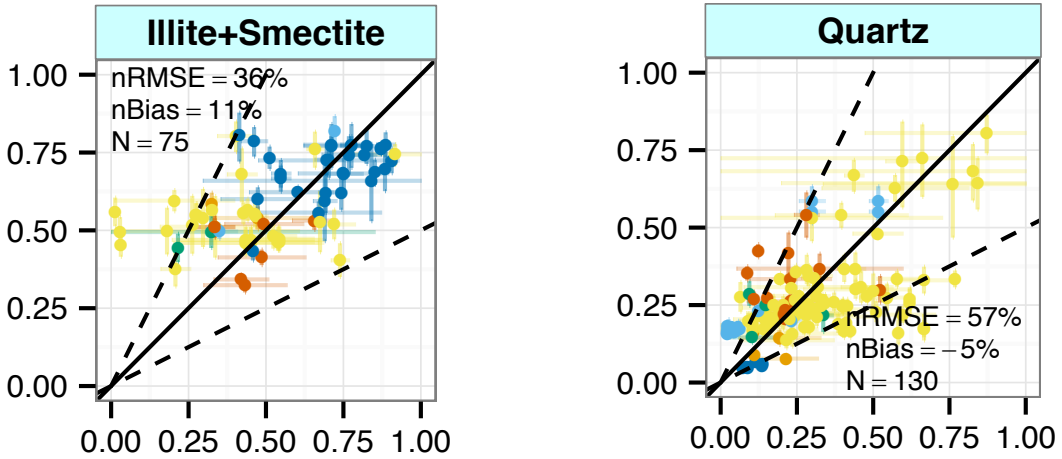

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